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APPLICATIONS OF DIGITAL MANUFACTURING IN MANUFACTURING PROCESS SUPPORT

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Abstract

In this study, the authors developed three new approaches and models for improvements related to manufacturing processes. The main focus was on planning in a digital environment before the actual manufacturing process is carried out. The first approach is digital manufacturing, which gives affords the opportunity for performing an entire manufacturing process in a virtual environment. In this way, engineers virtually define, plan, create, monitor, and control all production processes. The planning phase can be done simultaneously, while other manufacturing processes are already in place. In this way, processes can continue with no interruption. Various product lifecycle management tools have databases of various programs that are used for interfacing and communication with machinery, such as CNC machines and industrial robots. Ideally, after the manufacturing process has been verified in the digital environment, control data can be uploaded to numerically controlled machinery so that the production process can start. Two special models have been developed for more detailed insight into special types of manufacturing processes. The second approach represents a model for the unique type of production that takes into account all resources as the most important factor in the manufacturing processes. The main variables that were included in this model were the availability and the presence of all required manufacturing resources needed for every single manufacturing operation. The third approach represents a model for large-scale production that includes all significant parameters of a manufacturing process, as well as all required intermediate storage. The last two models were developed as parametric, and the users in the training process can easily make tests for different types of input data.

Introduction

Manufacturing process analysis is necessary for manufacturing companies to improve market competition [1]. The digital environment is used for student and workforce training. Various studies in the field of engineering education have proven that training is very effective with the use of the dynamic control of manufacturing process, where participants compare a simulation of the manufacturing process in the digital environment to the given set of parameters and the output [2]. In this current study, the digital manufacturing models proved to be a very useful tool for the training of the planners of production processes and for training and educating the mechanical engineering students. The use of the digital manufacturing models is suitable for designing new production systems or improving the existing ones [3]. A major advantage of the concepts is that the digital manufacturing models do not consume any materials, resources or energy; they operate only with data. As well, during the training process, the production process is not interrupted and, consequently, the equipment is not occupied and cannot be damaged [4].

Based on the findings of this study, two special concepts and models were developed that were shown to be useful for training during different levels of production. Manufacturing is a complex system that contains sets of tasks, materials, resources (including human resources, facilities, and software), products, and data [1]. Frequently, because of the intricacy of practical problems in manufacturing process management, their mutual interdependencies can lead to a mathematical model that is too complex to be solved by typical analytical methods [5]. For the purposes of detailed insight into special types of manufacturing processes, two models were developed: a model for unique type of production (UTP) and a model for large-scale production (LSP).

Model for Unique Type of Production

The concept for the model of a unique type of production treats operation as the elementary unit of the production process. The concept includes a logical rule that states that every single operation can be performed only when all of the required resources, the data sets, and the materials are available and present at the place of the operation being performed [6]. The sequence of operations representing the production process is shown in Figure 1.

The production process model for UTP, besides data, has the presence of resources taken into account, due to the unavailability of resources, where deadlocks frequently occur. Among the most important resources are counted transportation equipment, clamping equipment, cutting tools, measuring devices, machining centers, special tools and equipment, and human resources. Based on the logic model (see Figure 1), a simulation model of the production process for
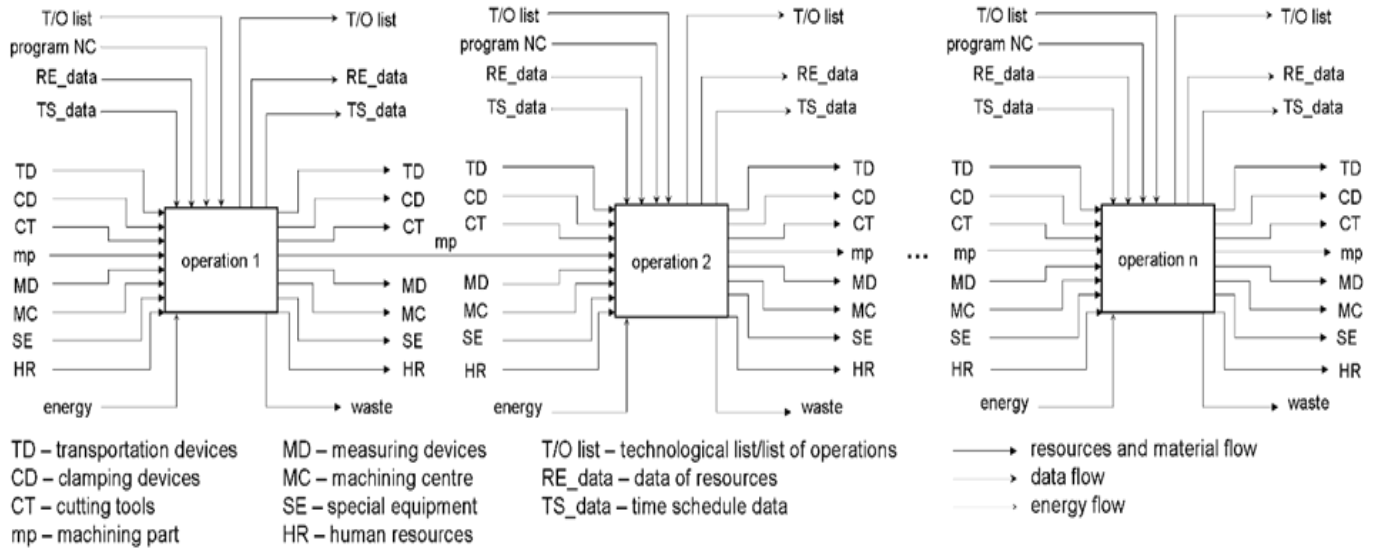
Figure 1. The Logical Scheme of the Simulation Model for a Unique Type of Production [7, 8]

TD – transportation devices   MD – measuring devices   T/O list – technological list/list of operations

CD – clamping devices   MC – machining centre   RE_data – data of resources

CT – cutting tools   SE – special equipment   TS_data – time schedule data

mp – machining part   HR – human resources

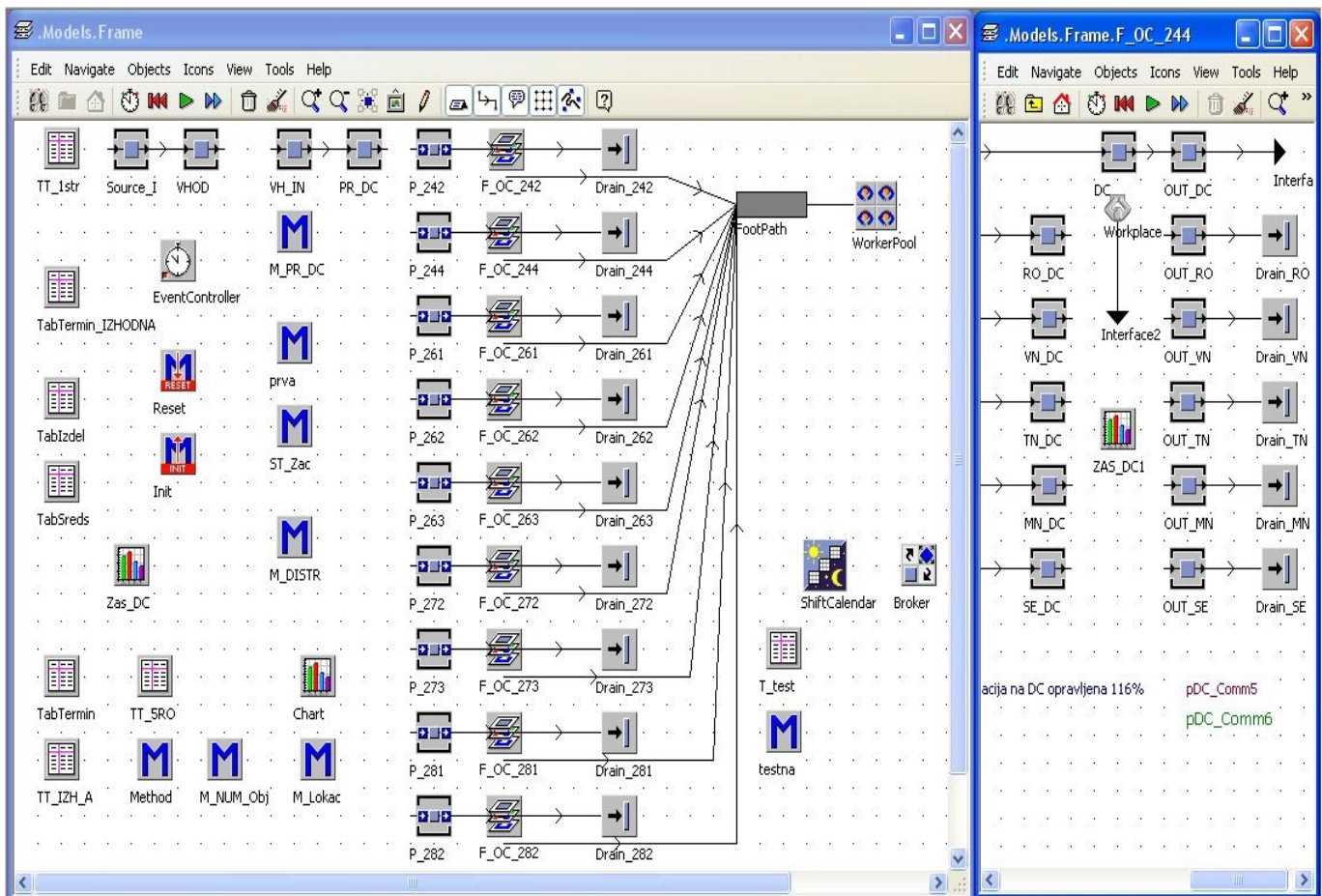resources and material flow

data flow

energy flow

**Figure 2. An Example of Virtual Factory for UTP in Plant Simulation [3]**

UTP was constructed in a computer environment— Tecnomatix Plant Simulation [9] (see Figure 2). The model

was designed as a parametric so that the user in the model inputs data intended for the real production process for the observed period. Among the input data are considered schedule plans, a list of available resources, a work calendar, and the number of available workers. After the initial setup, the user performs a simulation for the desired observation period or for production of the desired number of finished pieces. During the execution of the simulation, the speed can be set for simulation execution, and the simulation can be carried out step-by-step or stopped at any time. It is also possible to configure the production parameters for each production process. In the presented model are pre-designed indicators for real-time tracking of the number of finished parts, consumed production time, and occupancy analysis of individual resources.

The indicators can be displayed in text format on the screen or structured in table format. With simple additions, any indicator can be installed, or any calculations and analysis can be performed on an ongoing basis. A set of input data in the model contains information about the sequence of operations in the production process as well as a list of required resources necessary to perform every individual operation. An output, or acquired data, from the simulation for every individual operation covers the start time of operation execution, the end time of operation execution, and the anticipated duration of operation execution. In the execution of simulation, the user can optionally choose the starting date or observe the output of the production process after a specified number of calendar days.

Model for Large-Scale Production

In the concept for the model of a large-scale production, the assembly or production cell is treated as the elementary unit of the production process; and, in the model, the unit is treated as a sub-model (see Figure 3). The model was developed as parametric in a way that it allows the setting of the production process parameters, which depend on the product type.
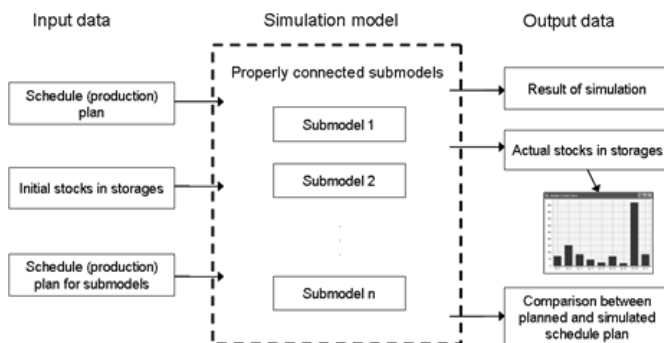
Figure 3. The Logical Scheme of the Simulation Model for Large-Scale Production

In the production process model for LSP, the efficiency of production units plays an important role. This means that the number of produced units depending on production time is significant. Inefficiency of production units occurs as a consequence of scheduled maintenance, parameter setting and calibration, insufficient quantities of materials, and unscheduled stoppages or failures. The next purpose of the model development is the real-time monitoring of stocks in intermediate storage. Stocks should not exceed the maximum capacity that the production process does not stop. Based on the logic model (Figure 3), a simulation model of the production process for LSP was constructed in a computer environment—Tecnomatix Plant Simulation (see Figure 4).

The model was designed as a parametric, where the user inserts the data into the model, which is aimed at the real production process for the observed period. The main schedule plan, the schedule plan for sub-models, the value of the initial stocks in storage, and the work calendar are considered in the input data. A simulation for the desired observation period, or for production of the desired number of pieces, can be performed after the initial setup of the model. The user has an option to set the speed of simulation execution, execute the simulation step-by-step, or stop at any time. The user also has an option to configure the production parameters for each production process in the model.

In this model, the indicators are pre-designed, which enables real-time tracking of the number of finished parts in intermediate storage, consumed production time, and occupancy analysis of individual production places. The indicators can be displayed directly on the screen in text format, in charts, or can be structured in table format. With simple additions, any indicator can be installed in the model, or any calculations and analysis can be performed on-line. Input data are comprised of the sequence of batch production on the production line. In this case, every batch represents a number of identical pieces in the series. An output or acquired data from the simulation for each batch covers the start time of production execution, the completion time of production execution, the expected duration of production execution, and the time spent producing one piece in a batch [9]. As with the UTP model, the user can optionally choose the starting date for performing the simulations or observe the production process for a specified number of calendar days.

In the simulation model, a special chart was designed (see Figure 5) through which an actual state of stock values in intermediate storage can be plotted. This allows the user to continuously monitor the stock movements and compare the values with the maximum capacity of intermediate storage.
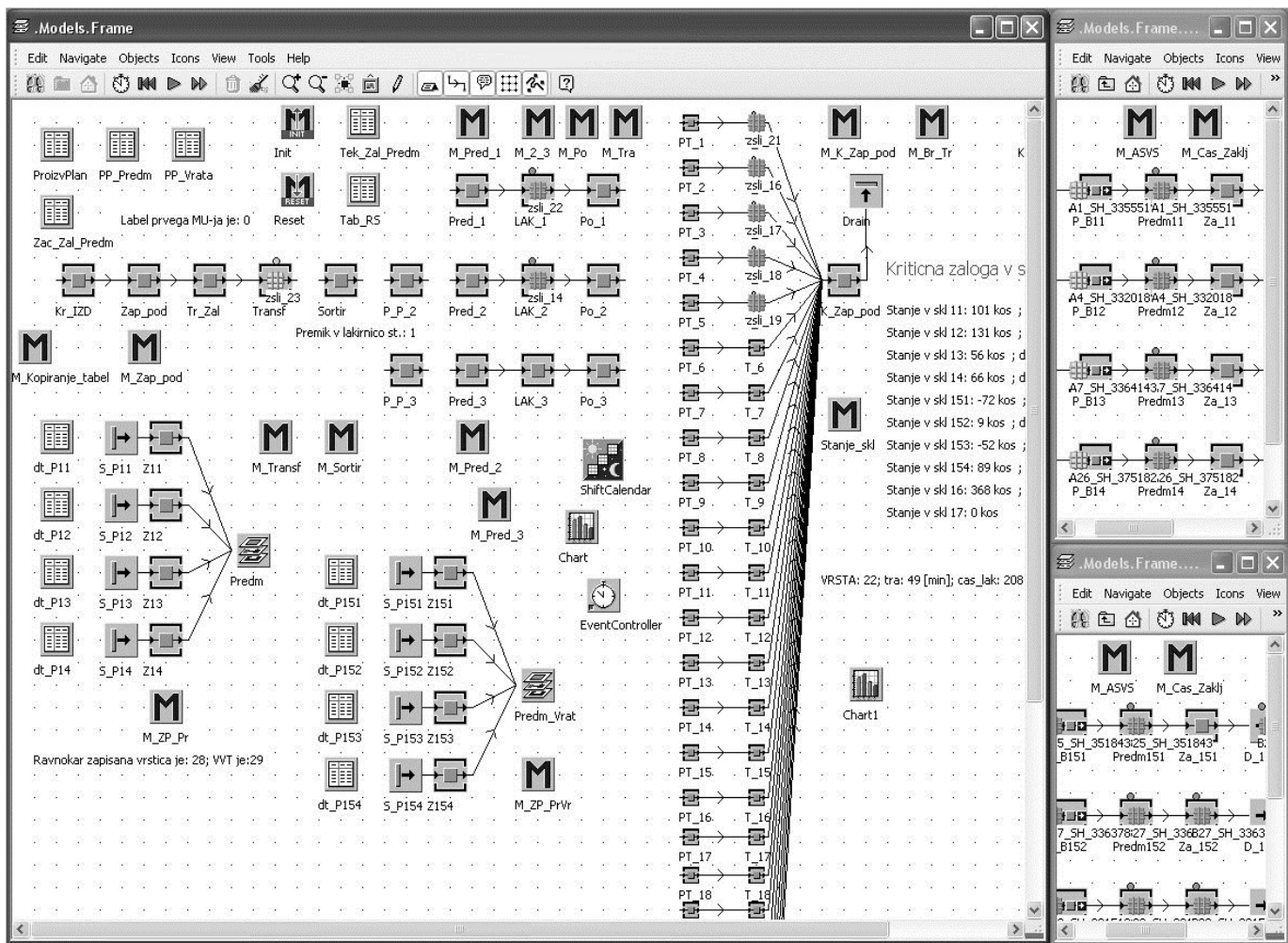
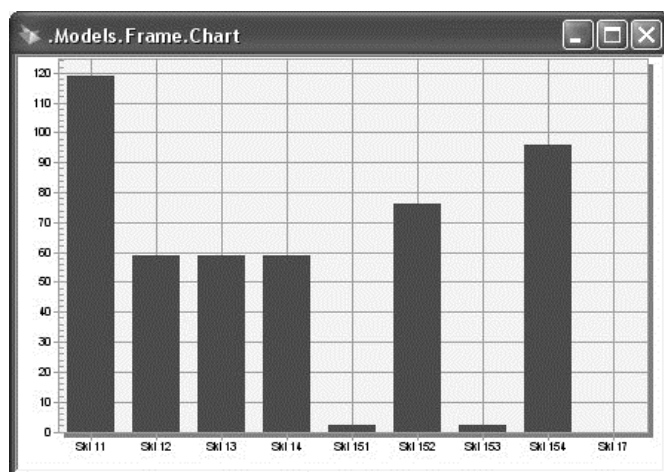**Figure 4. An Example of Virtual Factory for LSP in Plant Simulation**

Figure 5. An Example of the Chart for Monitoring the Values of Stocks in Intermediate Storage

Conclusion

Future research will focus on validation of existing approaches through data collection, analysis, and testing. Two models, which were developed as a part of this research study, will be evaluated, analyzed, and tested in the e-environment. The use of both special digital manufacturing models for the purposes of training and education brings a number of advantages. The first advantage is quickly obtaining the simulation results about the estimated execution of the schedule plan. The testing has proven that the execution of a production process in the digital manufacturing models, for an entire work shift, takes only a few minutes. Furthermore, with the testing of production plans in the digital manufacturing models, no intervention in the real production system is necessary and, thereby, does not cause any disturbances. Because of this, the possibilities of testing

different schedule plans are practically unlimited, where the behavior of the production system is observed as a function of time for an individual plan or only the outputs of the production system are observed. The models of production processes are designed parametrically, so it is easy to test the input data for different production plans for the purposes of learning. Developed models are user-friendly such that the user inserts the input data into the model, sets the process parameters, performs the simulation, and evaluates the results of the simulation.

Engineers and students can perform a simulation for an existing, or known, production system. They can observe the outputs of the model according to different arrangements in the digital manufacturing models. By using a simulation, they can also study a planned production system, where they test various configurations of the production system or test the response of the planned system to different settings, among which are included the number of shifts, a working calendar, the number of employees, different break times, different process times, the number of machines, variants of parallel processes, transport times, different transport routes, and different manners of transportation strategies for components. Based on the different settings and acquired responses, the engineers and students can determine the optimum production parameters.

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Biographies

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